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ENHANCEMENT OF DELAMINATION FRACTURE RESISTANCE OF COMPOSITES BY FIBER BRIDGING AND MULTIPLE CRACKS

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Abstract: Fiber composites based on long, aligned fibers are stiff and strong in the fiber direction but are prone to delamination, i.e. crack growth along interfaces between individual layers. Still, composite structures are being manufactured in larger and larger sizes. As an example, wind turbine rotor blades exceeding 75 meters in length are manufactured in one piece. Obviously, such large structure cannot be made free of defects. This motivates the development of composite materials that possess high damage tolerance by increasing delamination fracture resistance. In this study, we address two powerful mechanisms for increasing fracture resistance, viz., cross-over fiber bridging and the formation of multiple crack bridging cracks. They include different length scales.

Large-scale crack bridging by intact fibers or ligaments of multiple fibers that connect crack faces is a powerful mechanism for enhancing the macroscopic delamination fracture resistance [1]. Analytical micromechanical models of cross-over bridging have been developed for the prediction of macroscopic traction-separation laws (cohesive laws or bridging laws) [2, 3]. Relevant lengths parameters in these micromechanics models are the fiber radius or the thickness of bridging ligament.

Experimental studies have shown that for composites experiencing large-scale bridging, a secondary crack can develop along an interface next to the primary crack [4]. The resulting steady-state fracture resistance was found to be approximately twice that of a single crack. Theoretical considerations and numerical simulations have shown that the resulting steady-state fracture resistance can be nearly the sum of the work of the cohesive traction of the two advancing fracture process zones of the primary and secondary cracks [5]. The relevant length scales for this problem are the thickness of the layer between the two interfaces and the critical separation of the cohesive laws, at which he tractions go to zero.

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